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M. H. Knapp
Tenneco Chemicals

M. Freifeld
Tenneco Chemicals

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THE USE OF SYNTHETIC LUBRICANTS IN COMPRESSORS

Malcolm H. Knapp, Group Leader, Synthetic Lubricants Laboratory,
Research and Development Department, Tenneco Intermediates Division,
Tenneco Chemicals, Inc., Piscataway, New Jersey 08854

INTRODUCTION

A compressor is a device used to increase the pressure of a gas by either reducing its volume or by imparting an acceleration to it. The most abundant gas, air, is the one most frequently compressed. This discussion is related mainly to air compressors, although many of the principles also apply to compression of other gasses.

There are two main types of compressors, those operating by displacement and those operating by acceleration of the air. Included in the displacement type of compressors are reciprocating (piston), rotary vane and rotary screw types. They are characterized by high pressure ratios which put severe demands on the lubricant because of the high temperatures reached and the increased presence of water vapor. The dynamic (or kinetic) type which operate by acceleration of air, such as centrifugal and axial flow compressors, are generally designed and used for lower pressure ratios and high flow rate applications. The demands on lubricants for these latter applications are less severe.

What is the role of lubricants in compressors? They must (1) prevent or minimize wear of moving parts, (2) provide some cooling (without cooling the compression of room temperature air to 100 psig would cause a 400°F temperature rise and the compression to 500 psig, a 1000°F temperature rise), (3) reduce gas leakage (in dynamic compressors) so that capacities are maintained, (4) reduce frictional power loss, (5) flush away dirt and wear particles, and (6) protect the compressor from rust and corrosion both when it is operating and when idle.

This is what the compressor needs; what are the properties needed in a lubricant to help provide this performance?

1. Viscosity - the viscosity requirements of compressor lubricants vary considerably depending on the type, size, and location of the compressor. The range is broad; from 150-220 SUS at 100°F for rotaries, and from 300-1,000 SUS for reciprocating compressors.
2. Viscosity Index - this is a measure of the viscosity change with temperature. Higher VI's are desirable since they indicate less

"thinning" at high temperatures.

3. Pour Point - this is the temperature below which the oil is virtually solid. A typical requirement is a pour point at least 10°F below the lowest start-up temperature.
4. Stability - the oil must resist viscosity and acid build-up and the tendency to form lacquers and sludge.
5. Flash Point - a high flash point is needed for reasons of safety. A typical minimum is 400°F.
6. Autoignition temperature - a high auto-ignition temperature is desirable to minimize the danger of explosions. A typical minimum is 600°F. The higher, the better.
7. Rust and corrosion inhibition - this is usually provided by additives, but the base fluids can contribute to this property.
8. Demulsibility - the oil must be able to separate quickly and completely from the condensate derived from humidity in the air.

In 1966, a market survey carried out by Tenneco Chemicals indicated that a need existed for a type of lubricant which would provide improved performance in compressors. Petroleum lubricants, which in the past had done a satisfactory job, did not appear to be capable of handling the increasingly severe demands imposed by the newer high speed, smaller sized compressors operating at higher temperatures. One potential answer was believed to lie in synthetic lubricants, specifically designed for this application.

SYNTHETIC LUBRICANTS

Synthetic lubricants are a broad range of compounds derived from chemical synthesis rather than from the refining of petroleum oils or oils of animal or vegetable origin. The properties, availability, and costs of these synthetics vary considerably. Some of the synthetics which were, and are being considered for this application, are (1) Synthetic hydrocarbons, commonly polymerized olefins such as isooctene and isodecene, which are becoming available fully formulated over a wide range of viscosities, (2) Phosphate esters, which have long been used in this application primarily because of their good fire resistance, but which suffer from poor wear prevention characteristics, (3) Polyethers (or polyalkylene

glycols) which are somewhat limited in this application because of volatility and water solubility problems, but which have the advantage in that they tend to form volatile degradation products, (4) Silicones and fluorosilicones which have the advantage of good stability, good chemical resistance, and high viscosity indices, but the disadvantage of high cost, and (5) Carboxylic acid esters which are materials characterized by a balance of properties such as good thermal and oxidative stability, good film strength, and generally low volatility.

Since ester-based lubricants have long been successfully used in other demanding applications, it appeared that a diester-based lubricant formulated specially to meet the specific demands of an air compressor would provide the performance sought.

ROTARY COMPRESSOR LUBRICANTS

In 1967, work was started in the Synthetic Lubricants Laboratory at Tenneco Chemicals to find the most desirable ester and to formulate it to meet all the requirements of rotary vane and screw-type compressors. The rotary vane compressor, while not the one most commonly found in the field, is one of the most demanding on lubricants. The objective was to increase the lubricant change interval from 500 hours (typical of petroleum) to 4,000 hours. After considerable laboratory bench testing was carried out, a cooperative field test program was started with one of the leading compressor manufacturers. The program included both closely controlled in-house units and about 100 field installations. The condition of the oil was periodically monitored, as was the mechanical condition of the compressors. These were spot checked for lacquer and deposit build-up. The test was continued for over three years during which almost all of the test compressors logged over 4,000 hours without an oil change. Typical was 4,000 - 6,000 hours of operation for rotary vane compressors before the tests were terminated. Some rotary screw compressors were included and they logged over 8,000 hours. Not one of the rotary vane types had any lubricant-caused failure within 4,000 hours. The objective of increasing lubricant change intervals to at least 4,000 hours had indeed been met. In fact, it seemed that 4,000 hours was a conservative objective. Some compressors, which had been operated over 10,000 hours were disassembled and examined and found to be virtually lacquer-free. There was no observable gear wear and the vanes (non-metallic) were not chipped or worn enough to require replacement. It should be remembered that this was a type of compressor that had previously required 500 hour oil changes with petroleum oil-based lubricants.

The properties of this synthetic diester-based oil for rotary vane and rotary screw compressors are the following:

SYNTHETIC DIESTER OIL FOR ROTARY VANE AND ROTARY SCREW COMPRESSORS

Typical Properties

Viscosity @ 100°F, cSt	29.6 (140 SUS)
Viscosity @ 210°F, cSt	5.4 (44 SUS)
Viscosity Index	130
Pour Point, °F	-75
Flash Point, °F	490
Fire Point, °F	525
Autoignition Temperature, °F	765
Evaporation, 22 hours @ 210°F, %	0.9

RECIPROCATING COMPRESSOR LUBRICANTS

The second objective in this compressor oil development program was the formulation of an oil suitable for reciprocating compressors. The same oil could not be used because viscosity and other requirements are different. Of primary concern was the designing of an oil which would be suitable for both the lubrication of the crankcases as well as the cylinders. In the crankcase, oxidation resistance and good lubricating properties are needed to provide long-term lubrication of moving parts. Petroleum oils are not able to provide the very extended oil change periods desired. A problem of greater intensity, however, was cylinder lubrication. Here the lubricant is not reused, it goes through once and it is lost. The objective here was first to minimize lacquering and deposit formation and second, to minimize the amount of downstream oil. Our experience with the 140 SUS rotary oil and laboratory tests led us to believe that a similar, but heavier ester in the 500 SUS range at 100°F would produce a lubricant capable of achieving these results. Again both laboratory and field test sites were set up with a system of checking crankcase oil samples and inspecting the internal condition of the compressor, especially the air discharge valves. These valves are the most critical area for deposit formation. The objectives of the program were to provide a single, common oil capable of extending both crankcase oil changes and valve inspections to one-year intervals. During the three-year program, the formulation was optimized with the result that a synthetic diester-based oil was produced which met the objectives. The recommended valve inspection intervals have been extended from the typical 1,000 hours to 5,000 - 8,000 hours, depending on the type of compressor. This, of course, results in a considerable reduction in labor costs and downtime, and extends the period of maximum compressor efficiency.

The properties of this synthetic diester-based oil for lubricating reciprocating compressors are as follows:

SYNTHETIC DIESTER OIL
FOR RECIPROCATING COMPRESSORS

Typical Properties

Viscosity @ 100°F, cSt	108.1 (500 SUS)
Viscosity @ 210°F, cSt	9.5 (58 SUS)
Viscosity Index	63
Pour Point, °F	-30
Flash Point, °F	515
Fire Point, °F	550
Autoignition Temperature, °F	770
Evaporation, 22 hours @ 210°F, %	0.2

SYNTHETIC VERSUS PETROLEUM

How do these synthetic diester-based lubricants compare to petroleum-based lubricants? What are the advantages and disadvantages of this type of synthetic lubricant? Diester-based synthetic lubricants offer the following advantages:

1. Extended oil change intervals and minimized oil-related downtime because of the excellent oxidation and thermal stability of the esters. This allows the oil to resist viscosity build-up and minimizes the formation of sludge and varnish which can contribute to more expensive maintenance and loss of compressor efficiency. The excellent solvency of the ester also allows it to clean out deposits in older compressors, which had previously run on other types of oils.
2. Reduced oil consumption and less downstream oil due to the lower vapor pressure of the synthetic oil. Oil-use rates in vane-type compressors were reduced from 8 oz/1000 HP-hours to a little more than 1 oz/1000 HP-hours. Feed rates in reciprocating type cylinder lubricators were nearly cut in half because of this lower vapor pressure and the better lubricating characteristics of the esters.
3. Lower operating temperatures of 5 - 15°F which are produced by the higher heat capacity of the esters (5 - 10% greater) and their better thermal conductivity (15% greater).
4. Increased safety because of higher flash points (50 to 100°F higher) and high auto-ignition temperatures (750 - 775°F).
5. Higher film strength which minimizes part wear, again requiring less oil to do the job.
6. Good demulsibility, needed for condensate separation.
7. Non-foaming, important for providing good thin film lubrication and better cooling.
8. Very low toxicity, both external and internal.
9. Very wide operating temperature range, -70 to +450°F.

10. Compatibility with petroleum oils which may inadvertently be mixed.

The disadvantages are relatively minor, but the following should be mentioned:

1. Higher initial cost per gallon. This is, however, more than offset by lower maintenance costs. Over the extended performance intervals, the cost of operation with the synthetic lubricant has been found to be lower than with a petroleum lubricant because of the lower feed rates, fewer oil changes needed, and greatly reduced maintenance required.
2. Lesser compatibility with some plastics and seal materials. Attention must be paid to the materials of construction in the compressor. This lesser compatibility, however, has not been restrictive to their use in industrial plant air systems. Examples of compatible seal materials are high nitrile Buna-N and Viton rubbers.

CONCLUSION

A new generation of synthetic compressor lubricants has been developed which offers significant advantages over conventional petroleum-based oils in both rotary vane and rotary screw compressors as well as in reciprocating compressors. These are now available commercially for use in industrial applications.